Department of Economics

Working Paper No. 0215

http://www.fas.nus.edu.sg/ecs/pub/wp/wp0215.pdf

The Manufacturing Sector Did Contribute to Convergence Among the OECD Countries

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October 14, 2002

Abstract: This paper revisits the role of sectors in aggregate convergence. The existing evidence is inconclusive because its methodology depends sensitively on the conversion factor used to compare *sectoral productivity levels* across countries. This paper proposes a robust methodology -- β-decomposition -- to directly estimate how much the productivity growth in each sector and between-sector restructuring contribute to convergence. This methodology avoids the sectoral PPP-conversion-factor problem because it compares only sectoral growth rates and shares -- not levels -- across countries. The evidence suggests that productivity growth in both manufacturing and services were important in driving aggregate productivity convergence among the OECD countries.
The results are robust to the choice of base year.

JEL: O41, O47
Keywords: Convergence, β-Decomposition, Shift-Share Decomposition, Sectoral Decomposition

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1 Introduction

Did the manufacturing sector contribute to convergence in aggregate output per worker among the OECD countries? *How big* were the contributions of productivity growth and industrial restructuring to convergence? To answer these questions, I propose a methodology that directly decomposes aggregate productivity convergence into a component due to sectoral productivity growth, a component due to restructuring across broadly defined sectors, and a component due to their covariance. It turns out that productivity growth in both manufacturing and services contributed importantly to aggregate convergence, i.e., poorer countries enjoyed faster productivity growth in both manufacturing and services. Specifically, they accounted for about 40% of the tendency to converge. However, the contribution from between-sector reallocations was small, i.e., poorer countries experienced only slightly faster flow of employment into the more productive sectors. It accounted for slightly more than 10% of aggregate convergence.

Bernard and Jones (1996a, 1996b) study a related problem: they ask whether sectoral productivity converged as aggregate productivity did among fourteen OECD countries during 1970–1987. Their evidence suggests that while labor productivity and multifactor productivity converged in services, they showed no sign of convergence in manufacturing. Specifically, when they regress productivity growth on the logarithm of initial productivity at the *sectoral* level, they find an economically large and statistically significant coefficient on the initial productivity for services, but not for manufacturing. Consequently, Bernard and Jones (1996b) conclude that it was the service sector, not manufacturing, that drove aggregate productivity convergence.[1]

[1]However, applying the same method to U.S. states and industries, Bernard and Jones (1996c) find that it was productivity growth in the manufacturing sector that drove cross-state convergence. However, their results are difficult to interpret because they also find a number of counter-intuitive results because of measurement error. For example, they find that during 1963–1989, the states that have a large mining sector are the most productive in *all* sectors. Also, they find that in the aggregate, employment tend to shift from more productive sectors to less productive ones. More importantly, their analysis depends on the arbitrary choice of a benchmark/lead state, to which all states are assumed to converge to.

However, there are theoretical reasons to expect the manufacturing sector to drive convergence. A large literature has come to regard embodied technology – such as trade and equipment investment – as the key to economic growth (e.g., see Coe and Helpman (1995), Frankel and Romer (1999), Delong and Summers (1991)). Embodied technology enables fast catch-up from "relative backwardness" through cheap technological imitation rather than through costly innovation (e.g., see Barro and Sala-i-Martin (1997)). To the extent that manufacturing processes tend become standardized and their technology embodied, the manufacturing sector appears to be the perfect sector for catch-up growth and should therefore contribute to convergence.

Empirically, the established evidence of nonconvergence in manufacturing stated by Bernard and Jones (1996b) is inconclusive for two reasons. First, Sørensen (2001) argues that Bernard and Jones's (1996b) results are not robust because they convert sectoral productivity levels across countries using expenditure purchasing-power parities (PPPs) designed for total GDP. In particular, he shows that the convergence property of the manufacturing sector depends crucially on the choice of base year.[2] Thus, whether the manufacturing sector contributed to aggregate convergence remains uncertain. With the existing methodology, these questions cannot be addressed until the proper conversion factors for individual sectors become available.[3]

Second, by focusing on convergence within each sector, the existing methodology ignores the effect on aggregate convergence due to changes in economic structure. Absent market imperfections, economists expect factors of production to move from the less productive sectors to the more productive. Thus, the more productive sectors expand while the less productive ones contract.

[2] He devises several consistency tests based on the following necessary condition: if the proper conversion factors were used, measured relative productivity levels and thereby the results for convergence should be unaffected by the choice of base year, i.e., the year in which the fixed prices originate. Convergence in total industry and services did pass his consistency tests. However, he notes that simply because a set of conversion factors passes the consistency check does not mean that the conversion factors are valid, as his consistency tests are not based on sufficient condition.

[3] "...research relying on international comparisons of sectoral productivity and income should proceed with caution until these conversion factors [appropriate for converting sectoral outputs] are available" (Bernard and Jones, 2001, p.1169). See OECD (1996) for a review of the alternative approaches to measure the aggregate and sectoral conversion factors. As far as I know, there has not been any significant breakthrough in this field.

Even if a sector shows no sign of productivity convergence, it could still contribute to aggregate convergence through economic restructuring, freeing resources for the more productive sectors. In fact, the most notable trends in the OECD countries in the postwar period are a rise of the service sector and a decline of the manufacturing. Thus, the existing estimates only provide partial measures of aggregate productivity convergence.

Recent studies that use micro firm-level data have found continuous and large-scale reallocation of outputs and inputs between producers within narrowly defined industries in manufacturing that contributes significantly to productivity growth.[4] The evidence is more limited for services. However, the available evidence suggests that the contributions of reallocation and net entry appear to be even greater in selected service industries (see for example, Foster, Haltiwanger, and Krizan (2000) and Bartelsman and Doms (2000) for reviews). Although this literature also suggests that the amount of reallocation across sectors appears to be smaller, whether between-sector reallocation contributes to convergence is an empirical issue that has not been addressed.[5]

This paper proposes a methodology – β-decomposition – that simultaneously addresses the two empirical issues highlighted above. The proposed method combines Maddison's (1952) shift-share decomposition with the convergence regression. Instead of asking whether productivity converges in each sector and then inferring each sector's contribution to aggregate convergence, the β-decomposition methodology I propose directly estimates how much each sector contributes to aggregate convergence. By examining the sectoral contributions to aggregate convergence, this paper fills the gap between the micro literature studying longitudinal firm-level productivity dispersion and the macro literature on aggregate productivity convergence.

[4] For example, "for the United States manufacturing sector, roughly half of multi-factor productivity growth over the course of a decade can be accounted for by the reallocation of outputs and inputs away from less productive to more productive businesses" (Haltiwanger, 2000, p.4).

[5] "...4-digit industry effects account for less than 10 percent of the cross-sectional heterogeneity in output, employment, capital equipment, capital structures, and productivity growth rates across establishments" (Haltiwanger, 2000, p.5).

First, β-decomposition avoids the sectoral PPP-conversion-factor problem because it sidesteps the question of sectoral convergence – whether productivity converges in each sector. To estimate sectoral convergence, one needs to compare sectoral productivity levels across countries, which in turns calls for sector-specific PPP-conversion factors. However, to estimate β-decomposition, one only needs to compare (i) productivity growth and shares across industries and countries, and (ii) aggregate – but not sectoral – productivity *levels* across countries. The expenditure PPPs for total GDP are designed for exactly such broad-based comparisons.

Second, β-decomposition provides a complete account of the components that contribute to convergence. The account consists of three components: The first component measures how much the productivity growth in each sector contributes to aggregate convergence. The second component computes how much economic restructuring, measured by the shifts of employment across sectors, contributes to convergence. The last component captures the interaction effect between the first two components. Nothing is left out because these three components fully account for aggregate productivity convergence.

With this method, I show that productivity growth in manufacturing and services accounted for much of the absolute convergence in aggregate productivity among the OECD countries during 1970–90. This result is robust to the choice of base year. However, the contribution to convergence due to reallocations across sectors turns out to be small.

The remainder of this paper proceeds as follows. Section 2 proposes the β-decomposition methodology and discusses its interpretations. Section 3 applies the method to the data. Section 4 confirms robustness to the choice of base year. Section 5 concludes.

2 β-Decomposition: Accounting for Aggregate Productivity Convergence

One of the stylized facts in the empirical growth literature is the finding of absolute convergence among the OECD countries in the postwar period: economists typically find a negative β coefficient in the following convergence regression:

$$g(y_i) = \mu + \beta \ln y_{i0} + \epsilon_i, \tag{1}$$

where y_i is output per worker in country i, μ is the intercept, β is the coefficient estimate on the logarithm of initial output per worker (lny_{i0}), ϵ_i is an error term, and $g(.)$ denotes growth rate.[6] I refer to the β coefficient as aggregate convergence henceforth.[7] Thus, to account for aggregate convergence, the methodology I propose decomposes the β coefficient into a sum of the component β's.

Using the *shift-share decomposition identity* first proposed by Maddison (1952), aggregate productivity growth can be decomposed into a sum of different components due to the growth in k sectors:[8]

$$g(y) = \underbrace{\sum_{j=1}^{k} \underbrace{\alpha_j \left[\frac{\triangle y_j}{y_j}\right]}_{Productivity\,Growth\,in\,j}}_{Growth\,Effect} + \underbrace{\sum_{j=1}^{k} \alpha_j \left[\frac{\triangle s_j}{s_j}\right]}_{Shift\,Effect} + \underbrace{\sum_{j=1}^{k} \alpha_j \left[\left(\frac{\triangle y_j}{y_j}\right)\left(\frac{\triangle s_j}{s_j}\right)\right]}_{Interaction\,Effect}, \tag{2}$$

where y is aggregate output per worker, α_j is the initial output share of sector j in the economy, y_j is labor productivity in sector j, and s_j is employment share of sector j.

Equation (2) decomposes aggregate productivity growth into the sum of three components over k sectors: the first component represents the *growth effect*, i.e., the effect of sectoral productivity

[6] This is also known as β-convergence for obvious reason.

[7] For more discussions on the issue of convergence, see, for example, Mankiw, Romer, and Weil (1992), and Barro and Sala-i-Martin (1992).

[8] See, for example, Van Art (1996) for a recent application using European data.

improvements on aggregate growth, holding constant the employment structure of the economy; equation (2) also shows that the growth effect can be decomposed further into k components, where each component measures the productivity growth in each of the k sectors, holding constant employment structure and weighting each sector by its initial output share in the economy. The second component shows the *shift effect*, i.e., the effect on growth due to reallocations of labor across sectors, holding constant the relative productivity of each sector. The shift effect is positive or negative depending on whether sectors that are above average in productivity are increasing or decreasing their shares of employment. The third component captures the *interaction effect*, i.e., the covariance of the first two components. This term is positive if sectors that increase productivity more rapidly than average have increasing employment shares, and negative if these sectors have declining employment shares.

Equations (1) and (2) explain the same object, i.e., aggregate productivity growth $g(y)$. Combining the right hand side of the two equations, one immediately sees that initial output per worker ($lny_{i,t}$) must affect the growth of output per worker ($g(y)$) through three channels: within-sector productivity improvements (the growth effect), between-sector reallocations (the shift effect), and their covariance (the interaction effect). Substituting the shift-share decomposition identity (2) into the formula of any linear estimator of β in regression (1), it follows that

$$\beta = \sum_{j=1}^{k} \beta_{Productivity\,Growth\,in\,Sector\,j} + \beta_{Shift\,Effect} + \beta_{Interaction\,Effect}, \tag{3}$$

where β is the coefficient estimate on the logarithm of initial output per worker in equation (1), $\beta_{Productivity\,Growth\,in\,Sector\,j}$, $\beta_{Shift\,Effect}$, and $\beta_{Interaction\,Effect}$ are the respective coefficient estimates if the output-weighted productivity growth in sector j, the shift effect, and the interaction effect are used as the dependent variable in regression (1) instead.[9] Equation (3) defines

[9]For example, consider the simplest linear estimator – the OLS estimator. Let X denotes an $(n \times 2)$ regressor matrix, where column (1) consists of the constant term and column (2) consists of the logarithm of initial output per

β-decomposition. It states that poorer countries may grow faster than the richer ones if they have faster sectoral productivity growth, faster employment flows into the more productive sectors, or a combination of the first two factors. Specifically, $\beta_{Productivity\,Growth\,in\,Sector\,j}$ measures contribution to convergence from the productivity growth in sector j.

To illustrate, suppose that sector $m \leq k$ is the manufacturing sector. A negative β_m indicates that poorer countries tend to grow faster than the richer ones in manufacturing productivity in their transitions to the steady state. Thus, productivity growth in manufacturing must lead to aggregate convergence. In contrast, a positive β_m implies that it is the richer countries that experience faster productivity growth in manufacturing. Thus, the productivity growth in manufacturing would lead to divergence. Furthermore, the relative contribution of the manufacturing sector to aggregate convergence is readily measured by β_m/β. If this ratio were close to zero in absolute value, then the manufacturing sector could not have been an important sector behind aggregate productivity convergence. The sector that has the most negative ratio β_j/β, $j \leq k$ is the most important sector contributing to aggregate productivity convergence.

The last two estimates – $\beta_{Shift\,Effect}$ and $\beta_{Interaction\,Effect}$ – show the effect on convergence due to between-sector reallocations and the interaction effect. For example, a negative $\beta_{Shift\,Effect}$ indicates faster inflows of workers into the more productive sectors in poorer countries. In this case, economic restructuring would lead to aggregate productivity convergence. The interaction

worker. The OLS estimator of $\gamma = (\mu, \beta)' = (X'X)^{-1}X'g(y)$. Substitute the expression for $g(y)$ from equation (2) into the OLS formula above, we get:

$$\begin{aligned}
\gamma &= (X'X)^{-1}X'g(y) \\
&= \sum_{j=1}^{k}(X'X)^{-1}X' \quad \alpha_j \frac{\triangle y_j}{y_j} + \alpha_j \frac{\triangle s_j}{s_j} + \alpha_j \frac{\triangle y_j}{y_j} \frac{\triangle s_j}{s_j} \\
&= \sum_{j=1}^{k}(X'X)^{-1}X' \quad \alpha_j \frac{\triangle y_j}{y_j} + (X'X)^{-1}X' \sum_{j=1}^{k} \alpha_j \frac{\triangle s_j}{s_j} + (X'X)^{-1}X' \sum_{j=1}^{k} \alpha_j \frac{\triangle y_j}{y_j} \frac{\triangle s_j}{s_j} \\
&= \sum_{j=1}^{k} \gamma_{Productivity\,Growth\,in\,Sector\,j} + \gamma_{Shift\,Effect} + \gamma_{Interaction\,Effect}
\end{aligned}$$

In particular, $\beta = \sum_{j=1}^{k} \beta_{Productivity\,Growth\,in\,Sector\,j} + \beta_{Shift\,Effect} + \beta_{Interaction\,Effect}$.

effect and $\beta_{Interaction\ Effect}$ are typically very close to zero, suggesting little effect due to interaction between productivity growth and employment shift.

This sectoral decomposition methodology does not depend on *sectoral productivity-level* comparison. It depends on the growth rates of sectoral productivity and sectoral shares. Although it does depend on *aggregate productivity-level* comparison in the convergence regression, the existing PPP measures are designed for exactly such broad-based comparison. Thus, it avoids the sectoral PPP-conversion-factor problem highlighted by Sørensen (2001).[10]

With the β-decomposition in equation (3), it also becomes clear that the existing methodology that focuses on sectoral convergence only allows us to *infer* convergence due to the growth effect, but not convergence due to the shift effect and the interaction effect. Indeed, Bernard and Jones (1996b) argue that both convergence in output shares and convergence in sectoral productivity are needed to ensure aggregate convergence. They test whether countries are becoming more similar in output composition (see Bernard and Jones, 1996b, p1222 and p1225). They argue that since most countries show similar trends in the output shares of manufacturing and services (the dominant sectors) over time, they could concentrate on sectoral convergence in manufacturing and services. This paper goes further by directly estimating whether and how much economic restructuring contributes to aggregate convergence.

To perform β-decomposition in practice, I first decompose the growth rate of output per worker into the sectoral components using equation (2); I then successively regress these components on the logarithm of initial output per worker and a constant. The β coefficient estimates obtained from the successive regressions would measure the contributions to convergence from sectoral productivity

[10]Chad Jones pointed out that using the real output shares α_j's in the shift-share decomposition may nevertheless induce sectoral productivity-level comparison because $\alpha_j=(Y_j/Y)_{real} = (Y_j/Y)_{nominal} \times (P/P_j)$, where P and P_j are the general and sectoral price levels respectively. However, as the robustness test later reveals, calculating output shares using different base year prices (from 1980 and 1990) do not change the conclusion that both manufacturing and services are important in driving aggregate convergence.

growth, between-sector restructuring, and their covariance respectively.

An important fact about industrial production in the OECD countries is the rise of the service sector and the corresponding decline of manufacturing. I need to take this stylized fact into account in the shift-share decomposition so that I do not overstate the importance of the manufacturing sector and understate services. To do this, note that although the output shares α's are not constant over extended periods of time, they are roughly constant between consecutive years because year-to-year changes in the sectoral output shares are small. Consequently, to accommodate for changes in sectoral output shares, I first perform the shift-share decomposition for each year and then take the average over the sample period that I consider.[11]

2.1 How Does This Relate to Microeconomic Studies Using Firm-Level Data?

To see how this relates to the firm-level studies, note that equation (2) is the equation that Baily, Bartelsman, and Haltiwanger (1996) use to decompose the productivity growth in manufacturing into contributions due to productivity growth within individual firms, changes in employment shares across firms, and their covariance. Other microeconomic studies use very similar forms (see Griliches and Regev (1995), and Foster, Haltiwanger, and Krizan (2000)). Thus, these studies essentially apply the shift-share decomposition once more to the sectoral productivity growth, i.e., the first k terms in equation (2). They focus almost exclusively on manufacturing, with a few exceptions on selected service industries.

In other words, this paper provides an intermediate link between aggregate growth and firm-level growth within the same sectors. It emphasizes that an integrated and comprehensive industrial account for the growth of GDP per worker results from first decomposing aggregate productivity growth into sectoral productivity growth and restructuring across sectors, and then relating sectoral

[11] An alternative is to use average shares over the period.

productivity growth to productivity growth of individual firms and restructuring across firms within the same industries. For example, this framework can be used to investigate the role of restructuring across firms within narrowly defined industries in sectoral convergence. However, empirically such exercises are not yet feasible as we are still far from a complete industrial account of aggregate growth. Microeconomic firm-level studies in industries outside manufacturing are just beginning. Nevertheless, this framework provides a useful road map for thinking about these research.

3 Empirical Evidence

3.1 The Data and The Sample

The basic data source is the OECD International Sectoral Database (ISDB).[12] The empirical work in this section employs industrial production data for seven sectors in 13 OECD countries over the period 1970–1990, essentially the same sample used by Bernard and Jones (1996). The seven sectors I include are agriculture, construction, manufacturing, mining, services, utilities, and government plus other non-market producers.[13] The 13 countries are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Norway, Sweden, the United Kingdom, and the United States.[14]

Unless otherwise stated, all of the currency-denominated variables are in 1990 dollars, having been converted into US$ using 1990 expenditure purchasing-power parities (PPP's) for GDP. I measure labor productivity as value-added per worker, and the number of worker as total employ-

[12] See OECD Statistical Compendium (1999).

[13] All the sectoral classifications are taken directly from the ISDB except the services aggregate. In the ISDB, agriculture is AGR, construction is CST, manufacturing is MAN, mining is MID, utilities is EGW, government is PGS, and other non-market producers are OPR. The service sector is constructed by summing retail trade (RET), transportation/communication (TRS), finance/real estate (FNI), and community/personal services (SOC). The total is given by TET, which is also used to calculate sectoral shares.

[14] The Netherlands is excluded because it has missing values in services, a substantial component of total output. Although Italy and Belgium have missing values in mining, they are included as mining activities tend to be negligible and unimportant in the OECD countries. Finally, note that Germany has missing values for employment in the FNI sector for all years in the sample.

ment.[15] Admittedly, with only thirteen observations, it is meaningless to discuss the statistical significance of the estimates. Instead, I focus on re-assessing the findings of Bernard and Jones (1996) using the β-decomposition methodology and the economic significance of the estimates.

Table 1 shows the average output shares by country and sector for the period 1970–1990. The service sector was the dominant sector, producing an average of 45 percent of total output during 1970–1990. Manufacturing was on average about half the size of services, producing 22 percent of output. Government and other non-market producers were the third largest sector, producing 16 percent of output. Because outputs from this sector typically have no market prices and are produced with non-profit considerations, it is meaningless to discuss productivity growth in this sector. Thus, I ignore this sector in what follows. For the remaining sectors, average output shares were 3 percent for agriculture, 7 percent for construction, 2 percent for mining, and 3 percent for utilities respectively.

Table 2 shows the shift-share decomposition of aggregate productivity growth by country during 1970–1990 using equation (2). It turns out that the growth effect made up the bulk of aggregate productivity growth, although the shift effect was also non-trivial in some countries. Interaction effect was negligible in all cases. Specifically, for the whole sample, output per worker grew at an average rate of 2 percent per year, of which 1.65 percentage points came from sectoral productivity growth, 0.20 percentage points from between-sector employment restructuring, and -0.03 percentage points from their covariance. Some residual growth – 0.17 percentage points – were unaccounted for because of data omission in the ISDB, i.e., the sum of outputs of the seven sectors that I explicitly consider is less than the aggregate output reported in the ISDB.[16]

Total growth effect was positive for all countries, reflecting that sectoral productivity growth

[15] Value added and total employment are classified as GDPD and ET respectively in the ISDB.

[16] If outputs in the seven sectors did add up to the aggregate output reported in the ISDB, then there would be no residual and the decomposition identity would hold exactly.

contributed importantly to aggregate productivity growth. Total shift effect was also positive in all countries except Sweden. This means that sectors that were above average in productivity generally increased their shares of employment. Total interaction effect was negative for most countries, suggesting that sectors that were improving productivity more rapidly than average had decreasing employment shares. This finding is less surprising than it may appear and it need not imply any inefficiency; microeconomic firm-level studies often find that employment downsizing of a continuing business often accompanies large productivity gains.[17]

Table 3 further decomposes the growth effect into the productivity growth due to each sector, weighted by the sector's output share. It turns out that the manufacturing sector had the largest output weighted productivity growth. It was followed by services. Out of the 1.65 percentage points attributable to the growth effect, manufacturing and services contributed 0.66 and 0.58 percentage points respectively. The large contribution by manufacturing is particularly astonishing since the manufacturing sector was only about half the size of services in terms of output.[18]

3.2 Did the Manufacturing Sector Contribute to Convergence?

In this section, I estimate how much the productivity growth in each sector contributed to convergence in aggregate productivity using the β-decomposition in equation (3). Table 4 reports the results. Row (12) shows that aggregate output per worker converged at 2.46 percent per year. The preceding rows show the component β's. The service sector turns out to be the most important sector driving aggregate convergence. Out of the 2.46 percentage points, it accounted for 0.59

[17] For example, Foster, Haltiwanger, and Krizan (2000) argue that some technological innovations – such as the shift from large integrated mills to more specialized mini mills in the steel industry – may lead to substantial downsizing by plants that adopt the new technology. Furthermore, Haltiwanger (2000) points out that employment downsizing may reflect a restructuring involving increasing capital intensity and perhaps skill intensity that lead to improvement in labor productivity. However, these studies generally find that net entry of businesses does tend to increase labor productivity growth.

[18] It is worth emphasizing that since these are annual growth rates calculated using output shares in the previous year and then averaged over the sample period, they have already incorporated the long term trends of industrial production – declining output shares of manufacturing and increasing shares of services.

percentage points, or ((0.59/2.46)×100%=) 24 percent of aggregate convergence.

The manufacturing sector was the second largest contributor to convergence. In particular, it contributed 0.42 percentage points, or ((0.42/2.46)×100%=) 17 percent of aggregate convergence. It was followed by agriculture and construction. Each contributed 0.25 percentage points, or ((0.25/2.46)×100%=) 10 percent of total convergence. The mining sector contributed another 0.17 percentage points, or ((0.17/2.46)×100%=) 7 percent of the total. The contributions to convergence by agriculture, construction, and mining were more than proportional to their output shares. Productivity growth from other sectors – non-market and utilities – had little effect on aggregate convergence. In sum, the growth effect accounted for 1.78 percentage points, or ((1.78/2.46)×100%=) 72 percent of aggregate convergence.

Figure 1 illustrates β-decomposition of the growth effect. The horizontal axis is the logarithm of initial output per worker. The vertical axis plots the sectoral productivity growth. A negative slope implies that productivity growth in that sector contributed to convergence, i.e., poorer countries experienced faster productivity growth in that sector. A more negative slope implies a greater contribution, for instance, in manufacturing and services.

In summary, productivity growth in services and manufacturing was what drove aggregate productivity convergence among these 13 OECD countries during 1970–90. Together, they accounted for about 40 percent of aggregate productivity convergence, or ((0.59+0.42)×100%/1.78=) 57 percent of the growth effect. Finally, it is worth noting that although the manufacturing sector was on average only half the size of services, its productivity contribution to convergence was more than two-thirds of the contribution of services. Thus, productivity growth in manufacturing did contribute considerably to convergence.

3.3 Did Between-Sector Restructuring Contribute to Convergence?

The contribution to convergence from the shift effect turns out to be small. The estimate in Table 4 shows that it accounted for 0.33 percentage points, or only ((0.33/2.46)×100%=) 13% of aggregate convergence. The interaction effect fails to explain the tendency to converge, contributing only 0.03 percentage points to aggregate convergence. Thus, while between-sector restructuring did have some effect on aggregate productivity convergence, what really drove convergence was sectoral productivity growth, especially productivity growth in manufacturing and services.

Figure 2 shows the β-decomposition of aggregate convergence. The horizontal axis is again the logarithm of initial output per worker. The vertical axes plot the growth effect, the shift effect, the interaction effect, and the aggregate productivity growth respectively. Clearly, the contribution of the growth effect is the most pronounced.

Finally, some small residual effect, 0.32 percentage points, remain unaccounted for. As explained earlier, it arises because of data omissions in the ISDB: the seven sectors that I explicitly consider add up to less than the aggregate output reported in the ISDB. The residual effect captures anything not explicitly recorded in the ISDB. Hence, it is void of economic interpretation.

4 Robustness Checks for Base Year Effect

The above calculations use 1990 as the base year.[19] A natural question is whether the results are indeed robust to the choice of base year. To investigate this, I perform two robustness tests.

In the first test, I re-estimate the shift-share decomposition and β-decomposition using data with 1980 as the base year. I then compare them to those obtained using data with 1990 as the base year.[20] This is a comprehensive test for the base year effect because I re-estimate both growth

[19] Base year refers to the year in which the fixed prices originate.

[20] In other words, I re-estimate both equations (2) and (3) using output data measured in different base year prices. Thus, I ask whether the growth decomposition in equation (2) *and* the β-decomposition in equation (3) are robust

and convergence decompositions using different base year prices.

The data that use 1980 as the base year come from an earlier version of the ISDB – the one that Bernard and Jones (1996b) use. I change the sample period to 1970–85 because most data ended in 1987 in this version of the ISDB and there were some missing values in 1986–87. Panel A and B in Table 5 report β-decompositions obtained with 1980 and 1990 as the base year respectively. It turns out that in both cases, the manufacturing and service sectors consistently emerge as the most important sectors driving aggregate productivity convergence.

Not surprisingly, the absolute magnitudes of the estimates do depend on the choice of base year. For example, aggregate output per worker converged at 2.77 or 2.32 percent depending on which base year prices are used. Similarly, productivity growth in the manufacturing sector contributed either 0.65 or 0.40 percentage points depending on the base year chosen. However, what matters here is that the manufacturing sector contributed importantly to aggregate productivity convergence in both cases. Using 1980 as the base year, manufacturing accounted for ((0.65/2.77) ×100%=) 23 percent of aggregate convergence. Similarly, with 1990 as the base year, it explained ((0.40/2.32)×100%=) 17 percent of the tendency to converge.

Equally important, the service sector continues to drive aggregate convergence. It accounted for either ((0.65/2.77)×100%=) 23 or ((0.51/2.32)×100%=) 22 percent of aggregate convergence, depending on the base year chosen. The results for the other sectors are also robust to the choice of base year. Similarly, the contribution from between-sector restructuring remains small. Total shift effect explained either ((0.33/2.77)×100%=) 12 or ((0.29/2.32) ×100%=) 13 percent of aggregate convergence. The contribution of the interaction effect is negligible in both cases. Thus, the decompositions appear robust to the choice of base year.

The second robustness test investigates whether the choice of base year affects β-decomposition

to base year effect.

through the measurement of initial output per worker. Specifically, I follow Sørensen's (2001) procedures to construct measures of initial output per worker using prices for each base year between 1970 and 1991.[21] I then repeatedly substitute these measures into the right hand side of the regression to obtain β-decompositions for different base years. However, the dependent variable – the growth decomposition – continues to use 1990 as the base year.[22] Sørensen's procedures are not used to estimate growth decompositions for different base years because they are based on backward extrapolation using growth rates.

The only level comparison this methodology makes is very broad-based – that for aggregate output per worker. It does not compare sectoral productivity levels across countries. Therefore, the expenditure PPPs for total GDP are the correct conversion factors to use. Thus, a priori, one does not expect the results to be sensitive to the conversion-factor problem identified by Sørensen (2001).

Figure 3 summarizes the robustness checks for β-decomposition of the growth effect, and Figure 4 the robustness checks for β-decomposition of the aggregate convergence. The horizontal axis is the base years used to measure the initial output per worker. The solid line shows the corresponding β estimates, while the two dotted lines plot the 95 percent confidence interval. Since the lines are flat for all sectors and for all growth components, these plots confirm that the β estimates are indeed extremely robust to this consistency test.

In summary, the results are robust to the choice of base year. Although the absolute magnitudes of the estimates do change slightly when different base year prices are used, it is worth emphasizing that both manufacturing and services always emerge as the most important sectors that drove

[21] For details on the procedures I use to construct outputs measured in different base years, see Sørensen (2001, p1162).

[22] In other words, this test investigates robustness with respect to right hand side of the convergence regression. It does not ask whether the growth decomposition in equation (2) might be sensitive to base year effect, i.e., robustness with respect to left hand side of the convergence regression. In contrast, the first test examines robustness on both sides of the convergence regression.

aggregate productivity convergence.

5 Conclusion

This paper proposes a methodology – β-decomposition – to investigate whether and how much manufacturing and services contributed to aggregate productivity convergence among the OECD countries during 1970–1990. There are three main findings. First, the evidence suggests that sectoral productivity growth, especially in manufacturing and services, was the most important contributor to aggregate convergence. In other words, poorer countries caught up to richer ones through productivity improvements in both manufacturing and services.

Second, employment shifts across broadly defined sectors had limited impact on aggregate convergence. The process of employment restructuring *across* sectors was only slightly faster in poorer countries. However, the results say nothing about resource reallocations among firms *within* the same sector. Haltiwanger (2000) and Bartelsman and Doms (2000) point out that recent research using establishment and firm-level data has shown large-scale, ongoing reallocation of outputs and inputs across individual producers *within* sector. They show that these within-sector reallocations contributed significantly to sectoral productivity growth. Whether and how much these within-sector reallocations contributed to aggregate and sectoral productivity convergence are empirical questions that remain to be answered by future research. However, based on the findings of existing firm-level studies, it seems plausible that within-sector restructuring will emerge as an important driving force behind convergence.

Third, the methodology of β-decomposition and its findings are robust to the base year effect that Sørensen (2001) highlights. Though comforting, it is worth noting that Sørensen's (2001) consistency tests are based on necessary but not sufficient conditions.

The methodology I propose only examines the contribution of each sector to aggregate productivity convergence. It does not answer the question of whether there was productivity convergence *within* each sector across countries – the original Bernard and Jones's question. To answer that question conclusively, one indeed needs to compare sectoral productivity *levels* across countries, which is not possible without the correct sector-specific PPP conversion factors. To the extent that sectoral productivity growth was what drove aggregate convergence, one is tempted to infer that sectoral productivity did converge across countries. Though intuitive, this inference may not be straightforward. Thus, whether sectoral productivity did converge remains an empirical question to be addressed when the correct sectoral PPP conversion factors become available.

Finally, the use of labor productivity, instead of multifactor productivity, does restrict the depth of analysis, as a change in labor productivity confounds potential changes in technology and factor accumulation. However, calculating multifactor productivity at the sectoral level is unwieldy because it is difficult to obtain accurate measures of capital stocks for each sector over an extended period of time. In addition, it is unclear what the factor shares should be for different sectors. However, applying a similar *channel accounting* methodology to the aggregate data, Wong (2002) finds that it is total factor productivity (TFP) growth, not factor accumulation, that drives conditional convergence in aggregate output per worker. One expects similar patterns to hold also at the sectoral level. Furthermore, based on the findings of Bartelsman and Dhrymes (1994) on manufacturing plants, one expects much of the TFP growth at the plant level to take the form of within-sector across-plant reallocations.

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Table 1: Average Output Shares During 1970–1990

	Country	Agriculture	Construction	Manufacturing	Mining	Services	Utilities	Non-Market
1	AUSTRALIA	0.03	0.07	0.17	0.04	0.62	0.03	0.04
2	BELGIUM	0.02	0.07	0.21	.	0.49	0.04	0.15
3	CANADA	0.03	0.07	0.19	0.06	0.49	0.03	0.13
4	DENMARK	0.04	0.08	0.2	0	0.45	0.01	0.23
5	FINLAND	0.08	0.1	0.23	0	0.37	0.02	0.2
6	FRANCE	0.04	0.06	0.25	0.01	0.46	0.02	0.17
7	GERMANY	0.02	0.07	0.35	0.01	0.39	0.02	0.14
8	ITALY	0.04	0.08	0.21	.	0.4	0.06	0.16
9	JAPAN	0.04	0.1	0.26	0	0.35	0.02	0.11
10	NORWAY	0.04	0.05	0.18	0.06	0.48	0.03	0.16
11	SWEDEN	0.03	0.08	0.23	0.01	0.39	0.02	0.24
12	U.K.	0.02	0.07	0.24	0.03	0.44	0.02	0.19
13	U.S.A.	0.02	0.05	0.2	0.02	0.53	0.03	0.13
	Average	0.03	0.07	0.22	0.02	0.45	0.03	0.16

Notes: Belgium and Italy have missing values in mining sector.

Table 2: Shift-Share Decomposition of Aggregate Productivity Growth, 1970–90 (%)

	Country	Growth Effect	Shift Effect	Interaction Effect	Residual Effect	Growth in Output per Worker
1	AUSTRALIA	1.15	0.08	-0.07	0.15	1.31
2	BELGIUM	2.03	0.06	-0.04	0.32	2.37
3	CANADA	0.81	0.02	-0.06	0.1	0.87
4	DENMARK	1.6	0.08	-0.03	0.19	1.84
5	FINLAND	2.6	0.31	-0.02	0.02	2.92
6	FRANCE	2.17	0.34	-0.01	0.05	2.55
7	GERMANY	1.96	0.2	0	0.04	2.19
8	ITALY	1.53	0.42	-0.02	0.17	2.1
9	JAPAN	2.29	0.58	0	0.63	3.5
10	NORWAY	1.8	0.29	0.01	0.2	2.29
11	SWEDEN	1.55	-0.08	-0.03	0.06	1.5
12	U.K.	1.29	0.16	-0.05	0.32	1.72
13	U.S.A.	0.73	0.09	-0.02	0.01	0.81
	Average	1.65	0.20	-0.03	0.17	2.00

Note: Residual Effect = Aggregate Productivity Growth - Growth Effect - Shift Effect - Interaction Effect. It is due to data omission in the ISDB: the seven sectors I explicitly consider add up to less than total output in the ISDB.

Table 3: Decomposition of Total Growth Effect, 1970–90 (%)

		Output Weighted Sectoral Productivity Growth, $\alpha_j\,(\triangle y_j/y_j)$							Growth Effect
		Agriculture	Construction	Manufacturing	Mining	Services	Utilities	Government	$\sum_{j=1}^{7} \alpha_j\,(\triangle y_j/y_j)$
	Country	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
1	AUSTRALIA	0.06	0.07	0.38	0.15	0.37	0.14	-0.01	1.15
2	BELGIUM	0.09	0.11	1.03	.	0.38	0.29	0.13	2.03
3	CANADA	0.05	0.04	0.36	-0.11	0.46	0.06	-0.06	0.81
4	DENMARK	0.23	-0.02	0.49	0.05	0.78	0.05	0.01	1.6
5	FINLAND	0.33	0.23	0.84	0.02	1	0.05	0.13	2.6
6	FRANCE	0.21	0.12	0.79	0.01	0.88	0.08	0.09	2.17
7	GERMANY	0.1	0.1	0.8	-0.02	0.86	0.07	0.04	1.96
8	ITALY	0.12	0.09	0.86	.	0.44	0.02	0	1.53
9	JAPAN	0.14	0.12	1.08	0.02	0.7	0.07	0.16	2.29
10	NORWAY	0.15	0.1	0.31	0.51	0.63	0.04	0.05	1.8
11	SWEDEN	0.13	0.19	0.55	0	0.62	0.1	-0.05	1.55
12	U.K.	0.06	0	0.7	0.19	0.18	0.11	0.06	1.29
13	U.S.A.	0.04	-0.1	0.44	-0.03	0.3	0.03	0.05	0.73
	Average	0.13	0.08	0.66	0.07	0.58	0.09	0.05	1.65

Note: [8] = [1]+[2]+[3]+[4]+[5]+[6]+[7], i.e. growth effect equals the weighted sum of sectoral productivity growth, where the weights are sectoral output shares.

Table 4: β-Decomposition of Aggregate Convergence During 1970–90

	Sector	β	S.E.	N	R^2
1	Agriculture	-0.25	0.08	13	0.47
2	Construction	-0.24	0.08	13	0.41
3	Manufacturing	-0.42	0.31	13	0.14
4	Mining	-0.17	0.21	11	0.07
5	Services	-0.59	0.27	13	0.3
6	Utilities	0.01	0.09	13	0
7	Non-Market Producers	-0.11	0.08	13	0.14
8	Total Growth Effect	-1.78	0.49	13	0.54
9	Total Shift Effect	-0.33	0.21	13	0.18
10	Total Interaction Effect	-0.03	0.03	13	0.11
11	Residual Effect	-0.32	0.2	13	0.18
12	Aggregate Convergence	-2.46	0.68	13	0.55

Notes: The dependent variable in each row is the respective component of growth from the shift-share decomposition in equation (2). The regressors include only an intercept and the logarithm of initial output per worker in 1970. β is coefficient estimate on the logarithm of initial output per worker. Total output is given by TET in the ISDB. Netherlands is excluded from all regressions because it has missing values in value-added in most service industries in 1970. Belgium and Italy are excluded in the regression for mining sector because they have missing values in this sector. Since mining sectors are generally very small in the OECD countries, their omission should not affect the above results.

[a] [1]+[2]+[3]+[4]+[5]+[6]+[7]=[8].

[b] [8]+[9]+[10]+[11]=[12].

[c] The residual effect is due to data omission in the ISDB.

Table 5: Robustness Check I – β-decomposition of Aggregate Convergence During 1970–1985

A. Base Year 1980

	Sector	β	S.E.	No. of Obs.	R^2
1	Agriculture	-0.28	0.09	12	0.5
2	Construction	-0.11	0.13	12	0.07
3	Manufacturing	-0.65	0.42	12	0.19
4	Mining	-0.26	0.28	11	0.09
5	Services	-0.65	0.23	12	0.45
6	Utilities	-0.01	0.05	12	0
7	Non-Market Producers	-0.2	0.13	12	0.18
8	Total Growth Effect	-2.17	0.45	12	0.7
9	Total Shift Effect	-0.33	0.2	12	0.2
10	Total Interaction Effect	-0.07	0.04	12	0.24
11	Residual Effect	-0.2	0.27	12	0.05
12	Aggregate Convergence	-2.77	0.62	12	0.66

B. Base Year 1990

	Sector	β	S.E.	No. of Obs.	R^2
1	Agriculture	-0.26	0.08	13	0.5
2	Construction	-0.17	0.12	13	0.15
3	Manufacturing	-0.4	0.33	13	0.12
4	Mining	-0.2	0.16	11	0.15
5	Services	-0.51	0.27	13	0.24
6	Utilities	-0.03	0.08	13	0.02
7	Non-Market Producers	-0.11	0.12	13	0.07
8	Total Growth Effect	-1.68	0.50	13	0.5
9	Total Shift Effect	-0.29	0.22	13	0.14
10	Total Interaction Effect	-0.04	0.03	13	0.13
11	Residual Effect	-0.3	0.21	13	0.16
12	Aggregate Convergence	-2.32	0.66	13	0.52

Notes: The dependent variable in each row is the respective component of growth from the shift-share decomposition in equation (2). The regressors include only an intercept and the logarithm of initial output per worker in 1970. β is coefficient estimate on the logarithm of initial output per worker. Total output is given by TET in the ISDB. Netherlands is excluded from all regressions because it has missing values in value-added in most service industries in 1970. Belgium and Italy are excluded in the regression for mining sector because they have missing values in this sector. Since mining sectors are generally very small in the OECD countries, their omission should not affect the above results.

[a] [1]+[2]+[3]+[4]+[5]+[6]+[7]=[8].

[b] [8]+[9]+[10]+[11]=[12].

[c] The residual effect is due to data omission in the ISDB.

Figure 1: The Contribution of Sectoral Productivity Growths to Convergence During 1970–1990

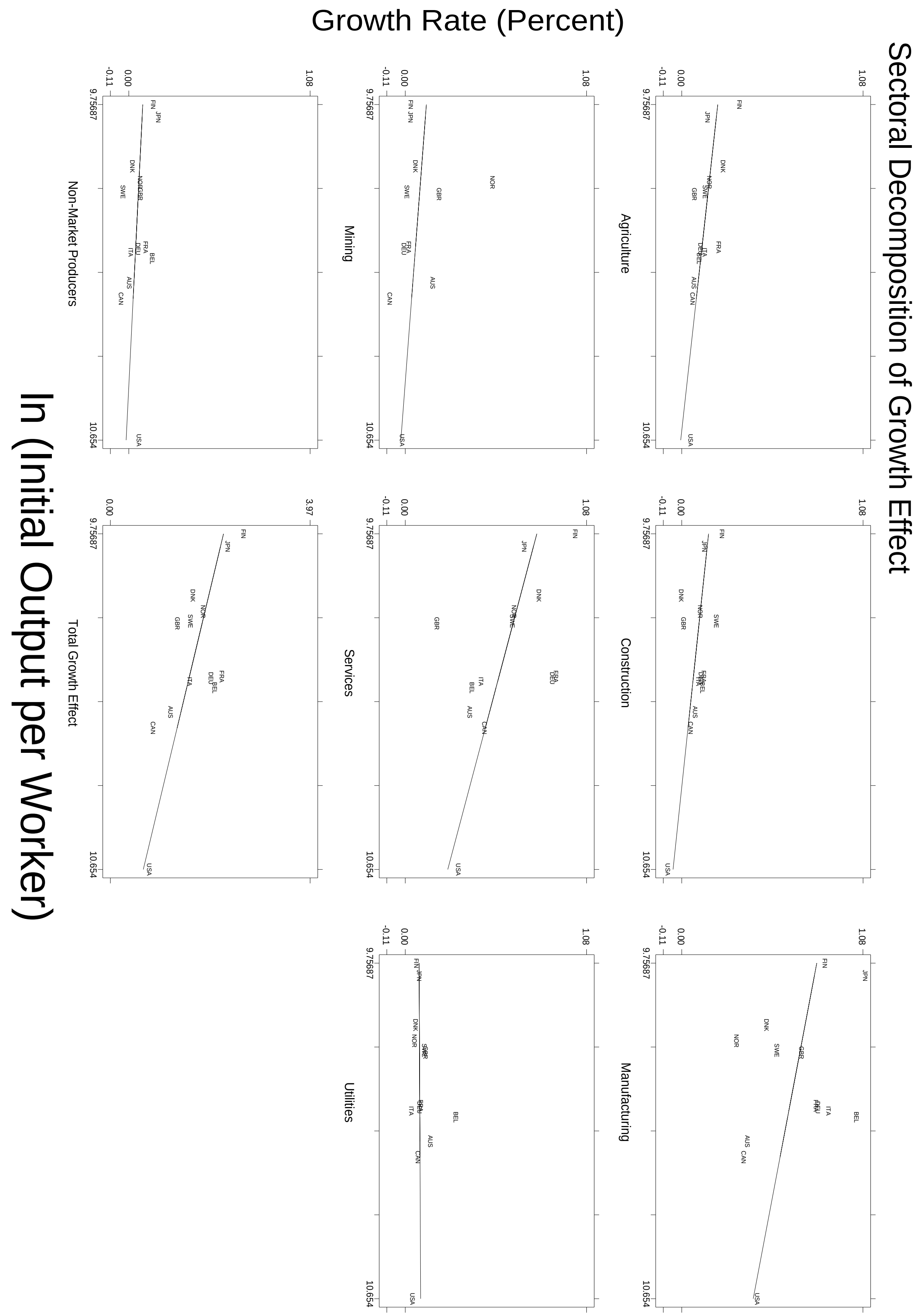

Figure 2: Shift-Share Decomposition of Aggregate Productivity Convergence During 1970–1990

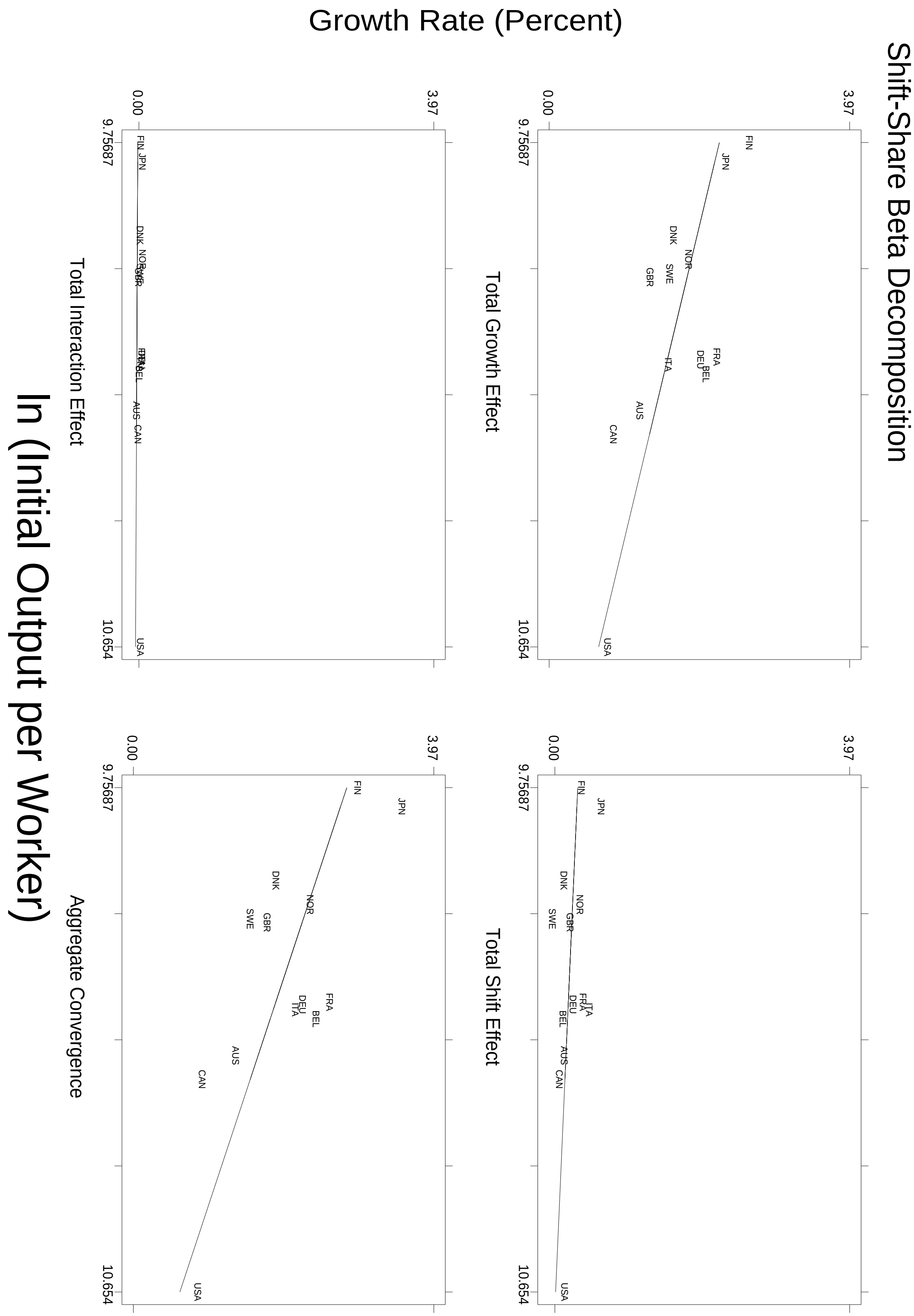

Figure 3: Robustness Check II – The Contribution of Sectoral Productivity Growths to Convergence (Base Years 1970–1991)

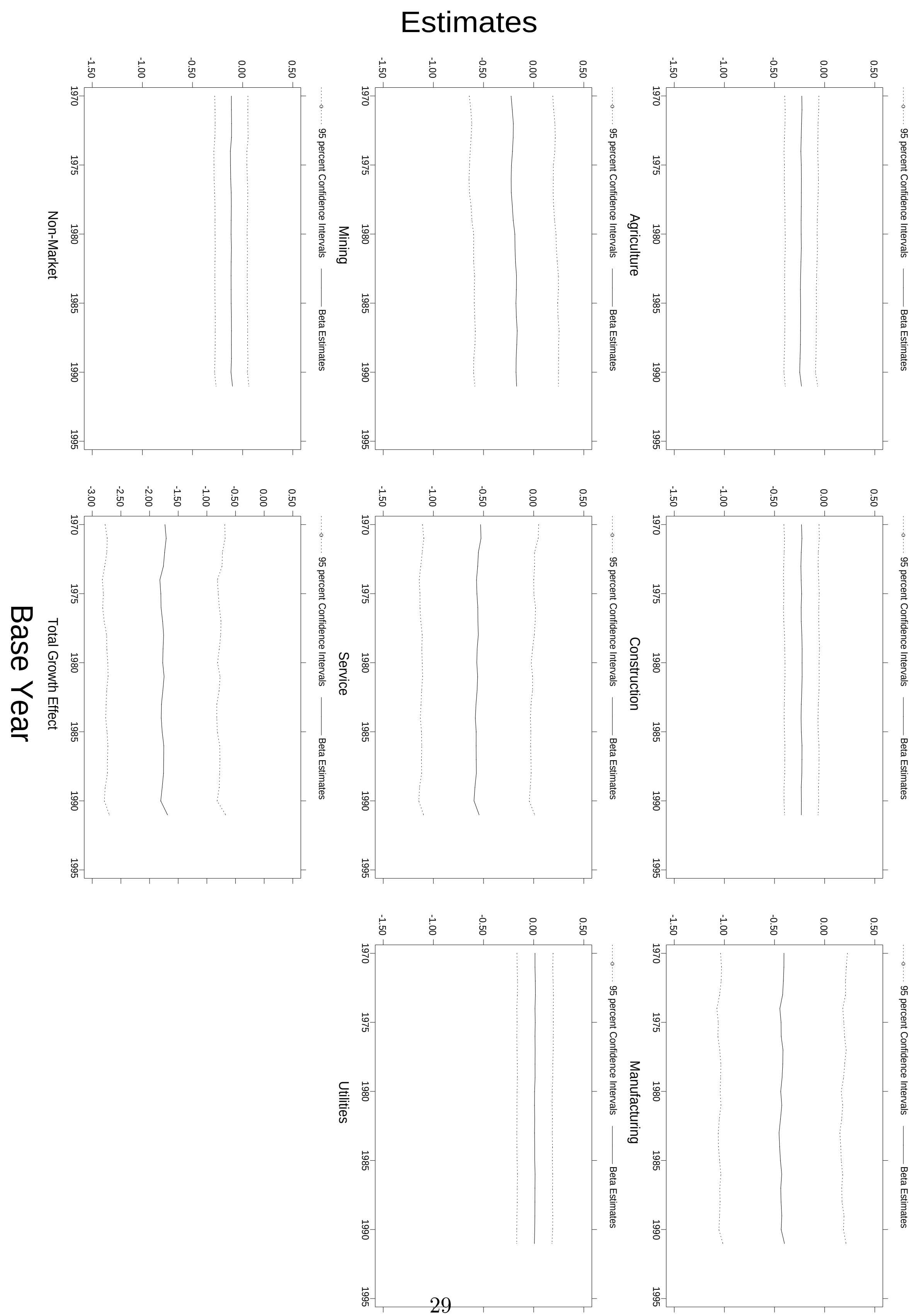

Figure 4: Robustness Check II – Shift-Share Decomposition of Aggregate Convergence (Base Years 1970–1991)